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DOUBLE CIRCUIT TRANSMISSION LINE PROTECTION AND FAULT CLASSIFICATION USING LINE TRAP AND ARTIFICIAL INTELLIGENCE

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ABSTRACT

The protection of double circuit transmission lines is a challenging task. The proposed work presents a protection technique based on the high-frequency transients generated by the fault to cover almost the total length of double circuit transmission lines. For this purpose, appropriately designed line traps are installed at terminals of the protected transmission line, and the Artificial Neural Network with suitable number of Neurons is used to classify the internal and external faults occur and which is based on the frequency spectrum of the current and voltage signals and identifying location and so therefore also it protect the remaining transmission line

KEYWORDS: Double circuit transmission lines, MATLAB, Line Trap Network, Neural network.

Introduction

An overhead transmission line is exposed to the environment and the possibility of experiencing faults on the transmission line is generally higher than other main components. When a fault occurs on a transmission line, it is very important to detect it and find its zone in order to make necessary repairs and to restore power as soon as possible. Distance relaying has been widely used for the protection of transmission lines. A distance relay has to perform the dual task of primary and back-up protection. The primary protection should be fast and without any intentional time delay. Back-up protection should operate if and only if corresponding primary relay fails. Distance relays are provided with multiple zones of protection to meet the stringent selectivity and sensitivity requirements. Zone 1 provides the fastest protection with no intentional time delay; the operating time can be of the order of one cycle.It is set to cover 80% of the line length because of the difficulty in distinguishing between faults which are close to remote bus. Zone 2 protection is delayed by co-ordination time interval. Zone 2 is set to protect primary line and also provides back up protection to 50% part of the adjacent line with 0.25–0.4 s delay. Setting of zone 3 is set to cover complete primary and adjacent line and up to 25% of remote line also with additional delay. so, various conditions such as remote in-feed currents, fault-path resistance and shunt capacitance degrades the performance of distance relays [1].The current differential protection scheme has been successfully applied to protect the entire line. However, the relay settings are difficult to decide due to line-charging currents and unobvious current variation during high resistance faults. Further composite voltage and current measurements were used to improve relay sensitivity [2] Faults in Overhead Transmission Lines.When fault occurs, the faulted phase voltage decreases and huge currents will flow which can burn out the components if not interrupted quickly

A: - Nature and Causes of Faults

Either insulation failure or failures of conducting path are the major causes for the occurrence of faults. In addition to this, faults are also caused due to over voltages which are occurring due to switching surges and lightening. Falling of conducting objects on overhead lines, encounter of flying birds, tree branches, direct lightening strokes, ice loading, creepers, storms etc.Some other reasons which can cause faults in overhead lines. Moisture in the soil, heat of earth, ageing of cables may lead to the solid insulation failure in cables, transformers and generators [1].

Types of faults:
1. Symmetrical faults
2. Unsymmetrical faults

B: - Effects of Faults

Following are the ill effects caused by a fault in a power system. Severe short circuit current may occur in the system due to fault which may prove fatal to the several equipment's of the power system and lead to the overheating of the system. Heavy current is also the reason behind the setting up of very high mechanical stresses. Failure of industrial loads, due to drop in the voltage of healthy feeders. Heating of rotating machines may occur due to unbalancing of currents and supply voltages arising due to short circuit. Loss in system stability. Continuity of power supply is adversely affected.

C: - Distributed Parameters of Line

Generally, lumped parameters are used for short and medium lines. But to enhance fault location accuracy, mainly in case of long lines, distributed parameters of the line are considered. The transmission line of unit length is considered as an electrical circuit which consists of series resistance R, series inductance L, shunt capacitance C, and leakage conductance G. R, L, C, and G are the parameters which are uniformly distributed along the whole length of the line. So, it is known as distributed parameter line. Each line consists of these four parameters and these parameters are recognized as primary constants of line.

Where,
R = Total series resistance/unit length (Ω/km)
L = Total series inductance/unit length (H/km)
C = Shunt capacitance/unit length (F/km)
G = Shunt conductance/unit length (℧/km)

Then,
Total series impedance, $Z = R + j$ ohm/km (3.1)
Total shunt admittance, $Y = G + \omega C$ mho/km (3.2)

The characteristics impedance (Z0) and propagation constant (γ) parameters are Extremely useful parameters used for analyzing transmission line. These parameters are known as secondary constants of the transmission line and these parameters are obtained in the form of primary constants. Even though, these parameters are known as constants but if frequency is changed then these will vary.

Where

Surge impedance, $Z0 = \sqrt{\frac{R + j\omega L}{G + j\omega C}} = \sqrt{\frac{Z}{Y}}$

Surge impedance will be the characteristics impedance of the lossless line.

Propagation constant, $\gamma = \sqrt{(R + j\omega L)(G + j\omega C)} = \sqrt{ZY}$

Since, γ is a complex quantity, it is given as: $\gamma = \alpha + j\beta$
α = attenuation constant
β = phase constant

And, the impedance of the distributed parameter line is calculated as given by equation
$Za = 2{*}Z0 \sinh(\gamma * l)$

Where, Za is the actual impedance of the distributed parameter line and, l = length of transmission line in km.

Materials and Methods:

Main power system model:

This project implementation will be done using MATLAB Simulink software. The major blocks will be design in MATLAB Simulink as follows:

A. Simulation of transmission line using distributed parameter transmission line.

B. Simulation of wavelet signal analysis block using wavelet toolbox.

C. Simulation of complete double circuit based power system components using sim power system toolbox.

D. Simulation of various transmission line faults and unbalance load condition for analysis of design protection scheme.

E. Design of neural network for fault classification using neural network toolbox.

F. Training of neural network for various simulated fault condition using neural network toolbox.

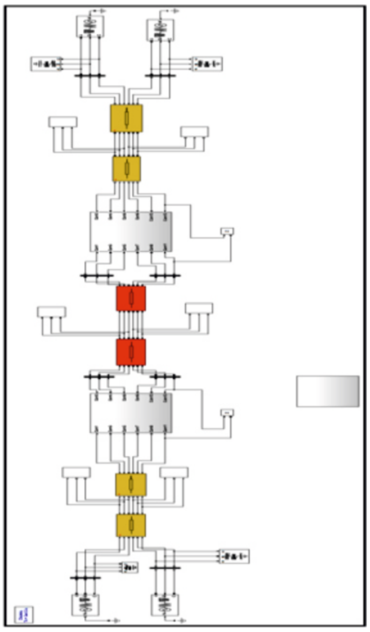

Figure 1: MATLAB simulation model of power system

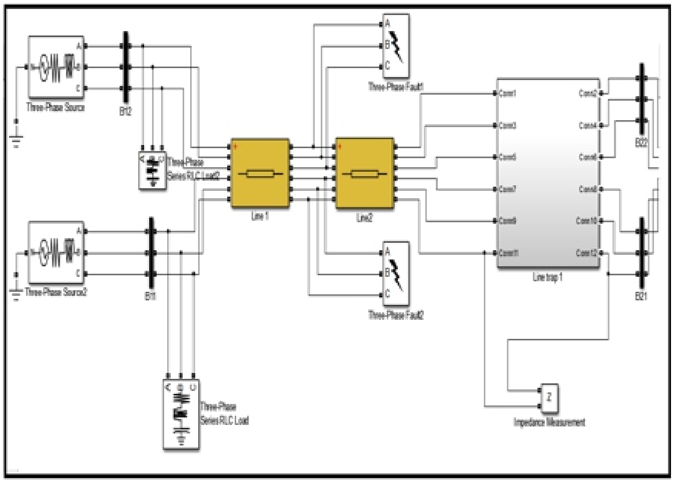

Figure 2: MATLAB simulation model of zone 2 of main power system

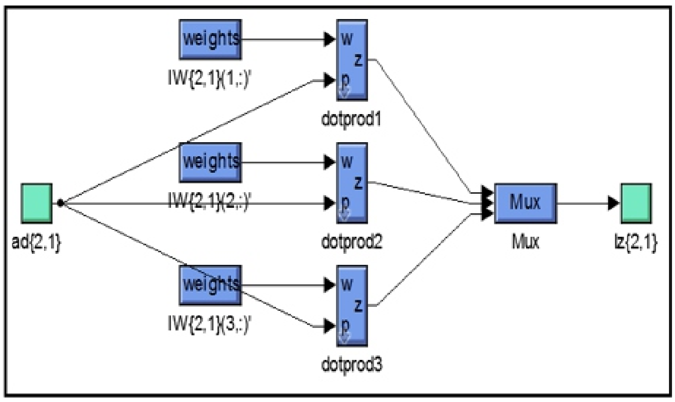

Figure 3: Architecture of layer 2 of ANN for fault zone identification shows weights with value

Results:

line trap :

The frequency response of the designed line trap is shown in figure 4, considering the frequency band of the fault-induced HF transients, which is mostly in the range of 10–100 kHz, the resonance frequency of the line trap is tuned at 50 kHz.

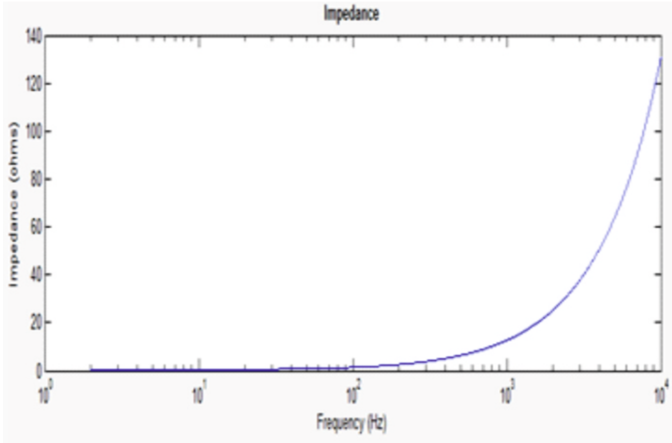

Figure 4. Impedance of line trap at high frequency transients

Power system voltage and current :

In that section MATLAB simulation model result for different fault condition and different fault location simulated and analyzed. In MATLAB simulation model of line there are 22 fault cases like AG, BG, CG, ABG, BCG, ACG, AB, BC, AC, ABCG, ABC, A'G, B'G, C'G, A'B'G, B'C'G, A'C'G, A'B', B'C', A'C', A'B'C'G, A'B'C' simulated at different fault location of six phase transmission line.

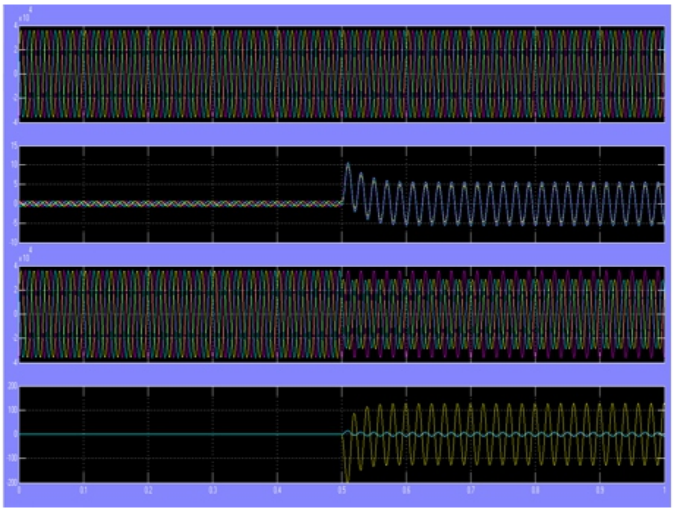

Figure 5. Six phase RMS voltage and RMS current waveform when LG (AG) fault takes place on line at 100km in zone 1 from reference bus bar B22

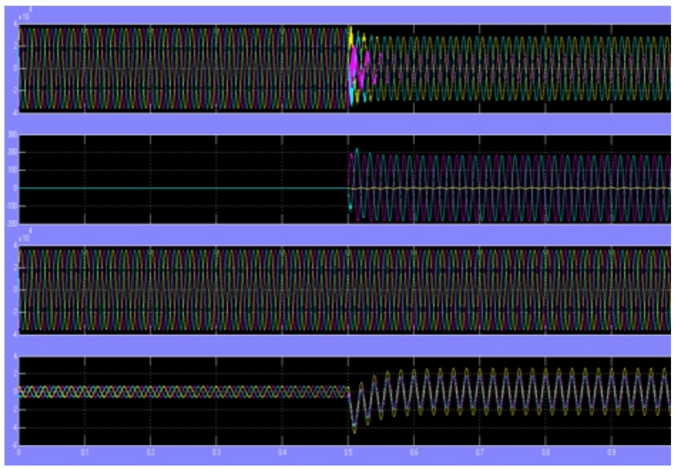

Figure 6. Six phase RMS voltage and RMS current waveform when LLG (B'C'G) fault takes place on line at 80 km in zone 1 from reference bus bar B22

Power system parameter measurement: -

The power system six phase RMS voltages and RMS currents measured at bus bar B22 during different fault condition and normal condition for generation of data set for training neural network for both fault type classification and fault zone identification. Table 1 shows the different values measured of RMS voltage for six phase line also Table 2 shows the different values measured of RMS current for six phase line for fault cases at different fault zone of line.

Table 1: Six phase transmission line rms voltage at different fault condition.

S.N.	Zone	Location	Type of fault	VA B21	VB B21	VC B21	VA' B22	VB' B22	VC' B22
1	Zone 1	100km (Bus 1&2)	AG	2.42*104	2.42*104	2.73*104	18890	24170	21500
2	Zone 1	80km (Bus 1&2)	ABG	2.42*104	2.42*104	2.73*104	8229	20200	21230
3	Zone 1	60 km (Bus 1&2)	A'B'	6773	22570	23420	2.42*104	2.42*104	2.73*104
4	Zone 2	20 km (Bus 3&4)	ABG	2.42*104	2.42*104	2.73*104	3034	19690	20000
5	Zone 2	40 km (Bus 3&4)	A'C'G	18050	17840	6101	24170	27290	0.4001
6	Zone 3	100 km (BUS 5&6)	A'C'	20930	20710	11550	24260	24170	27290
7	Zone 3	125 km (BUS 5&6)	ACG	24260	24170	27290	19210	19030	13050

Table 2:Six phase transmission line rms currents at different fault condition

S.N.	ZONE	Location	TYPE OF FAULT	IA B21	IB B21	IC B21	IA' B22	IB' B22	IC' B22
1	Zone 1	100km (BUS 1&2)	AG	3.17	3.84	3.74	88.48	5.695	5.534
2	Zone 1	100km (BUS 1&2)	BG	4.29	3.6	4.299	6.271	96.41	6.32
3	Zone 1	100km (BUS 1&2)	CG	3.79	3.905	3.222	5.539	5.595	83.79
4	Zone 1	100km (BUS 1&2)	AB	0.3997	0.4535	0.4052	123.3	123.5	0.4051
5	Zone 1	100km (BUS 1&2)	BC	0.3997	0.4534	0.4052	0.3994	117.7	117.7
6	Zone 2	20 km (BUS 3&4)	B'C'	0.3996	192.8	192.7	0.4	0.4533	0.4045
7	Zone 2	20 km (BUS 3&4)	A'C'	175.4	0.4533	175.4	0.4	0.4533	0.4045
8	Zone 2	20 km (BUS 3&4)	A'B'G	204.4	210.8	0.2997	0.4233	0.495	0.3417
9	Zone 2	20 km (BUS 3&4)	B'C'G	0.2944	207.5	189.6	0.3391	0.4865	0.4343
10	Zone 2	20 km (BUS 3&4)	A'C'G	185	0.3345	181	0.4454	0.3837	0.4451
11	Zone 2	20 km (BUS 3&4)	A'B'C'G	217.5	236.3	205.2	0.4	0.4533	0.4045
12	Zone 3	125 km (BUS 5&6)	AG	4.823	4.185	4.293	88.42	6.424	6.595
13	Zone 3	125 km (BUS 5&6)	BG	4.796	5.46	4.787	7.299	96.41	7.245
14	Zone 3	125 km (BUS 5&6)	CG	4.332	4.223	4.867	6.432	6.386	83.8
15	Zone 3	125 km (BUS 5&6)	AB	0.4002	0.4532	0.4042	120.8	120.6	0.4043
16	Zone 3	125 km (BUS 5&6)	BC	0.4001	0.4533	0.4042	0.3999	115.2	115.2

Training of Neural Network:

Neural network training for fault classification and fault zone identification. For that two separate neural network structure are utilized but input for both network becomes same i.e. bus bar 22 measurement parameters. That parameters are each six phase RMS voltage i.e. Va, Vb, Vc, Va', Vb',Vc' and each phase RMS current Ia, Ib, Ic, Ib', Ib', Ic'. Neural network train for different types of 200 fault cases. This fault cases simulate in three zone of transmission line. Total three unsymmetrical and two symmetrical fault case simulate on each phase of transmission line at different 10 fault location of transmission line. Always transmission line simulate for 1 seconds of simulation time and each fault event takes place at 0.3 second. During that fault resistance becomes 0.001 ohm and ground resistance 0.001 ohm for all types of fault simulation.

Training of ANN1 for fault type classification:

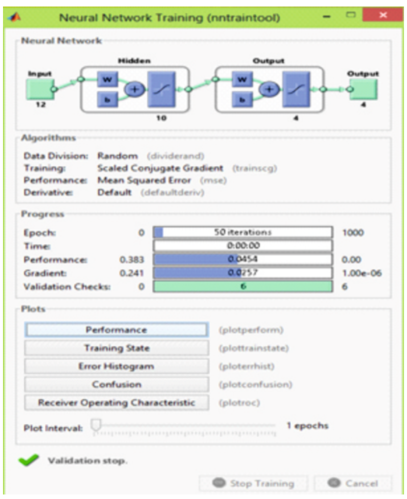

Figure 7: Training performance window and parameter window for ANN1 for transmission line fault classification

Conclusions:

Line trap is present high impedance at the carrier frequency of 100 kHz while presenting negligible impedance at the power supply frequency 50 Hz.ANN1 for fault type classification classify 93% fault cases and remaining fault case data not classify. It means that for remaining 7% data set neural network was in confusion state for classify the fault. Results shows that 61.5 % data are perfectly classify the fault zone and remaining fault case data not classify using neural network 2 (ANN2). It means that for remaining 48.5 % data set neural network was in confusion state for classify the fault zone. This proposed approach needs more time for generating the training data set required for training neural network hence it is time consuming method during training but after successful training both neural network classify the fault class and fault zone.

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